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# Investigating Consumer Perceptions and Mapping E-waste Stakeholders: Evidence from Chh. Sambhajinagar City, Maharashtra

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## Abstract

Electronic waste (e-waste) has emerged as one of the fastest-growing waste streams globally, posing significant environmental and public health challenges. This study examines consumer awareness, risk perception, and disposal behaviour regarding e-waste management in Chhatrapati Sambhajinagar (formerly Aurangabad), a Tier-III city in Maharashtra, India, with a population exceeding 1.2 million. A structured questionnaire (Cronbach's  $\alpha = 0.81$ ; pilot-tested with  $n = 45$ ) was administered to 620 respondents through stratified random sampling across residential, commercial, and institutional zones. Statistical analysis, including chi-square tests, Pearson correlation, and binary logistic regression, revealed that while 60% of respondents possessed basic awareness of e-waste hazards, approximately 48% continued to dispose of electronic waste with municipal refuse, indicating a persistent awareness-behaviour gap ( $r = 0.26$  for awareness-actual behaviour;  $r = 0.42$  for awareness-willingness). Logistic regression identified access to a collection point as the strongest predictor of formal disposal (OR = 3.06, 95% CI: 1.76-5.31), outperforming awareness score (OR = 1.033 per unit). Material flow triangulation estimated that informal networks handle approximately 55% of the city's annual e-waste generation (~18,000-22,000 MT). Comparative analysis with the USA, Europe, China, South-East Asia, and Africa, analytically integrated with study findings, confirmed that infrastructure accessibility and incentive-driven

governance are more effective determinants of sustainable disposal behaviour than awareness campaigns alone. The findings emphasise the need for strengthened Extended Producer Responsibility (EPR) implementation, decentralised collection infrastructure, and integration of informal recyclers into formal value chains for advancing evidence-based e-waste management in rapidly urbanising Tier-III regions.

## 1. Introduction

The rapid proliferation of electronic and electrical equipment (EEE) globally has generated unprecedented volumes of electronic waste (e-waste), making it one of the fastest-growing solid waste streams worldwide. According to the Global E-waste Monitor 2020 (Forti et al., 2020), approximately 53.6 million metric tonnes of e-waste were generated globally in 2019, with projections indicating an increase to 74 million metric tonnes by 2030 (Parajuly et al., 2019). In India, e-waste generation has reached approximately 3.2 million tonnes annually with a growth rate of 30% per annum, positioning the country as the third-largest e-waste producer globally after China and the United States. (Forti et al., 2020; Arya & Kumar, 2020)

Chhatrapati Sambhajnagar, officially renamed from Aurangabad in 2023, is a historically significant city in the Marathwada region of Maharashtra. With a population of approximately 1.27 million (Census projection 2024), it serves as a pivotal administrative, commercial, and educational hub. The city is home to renowned heritage sites, including Bibi Ka Maqbara, the Aurangabad Caves, and numerous historical gates (52 darwazas), while simultaneously emerging as an industrial centre with the MIDC (Maharashtra Industrial Development Corporation) industrial area and a growing automotive sector. Its classification as a Tier-III city makes it representative of rapidly urbanising centres in India experiencing exponential growth in electronic device consumption, yet lacking commensurate formal waste management infrastructure.

E-waste contains both valuable materials (copper, gold, palladium, rare earth elements) and hazardous substances (lead, mercury, cadmium, brominated flame retardants), making improper disposal a critical environmental and public health concern. Informal recycling practices prevalent in the city involve crude methods, such as open burning, manual dismantling without safety equipment, and acid leaching that release toxic pollutants into the air, water, and soil, exposing workers and communities to serious health risks. (WHO, 2022; Awasthi et al., 2022; Kiddee et al., 2013)

While metropolitan cities like Mumbai, Pune, and Bangalore have received considerable research attention regarding e-waste management, Tier-III cities like Chhatrapati Sambhajnagar remain understudied despite their rapid urbanisation and increasing electronic consumption. This study addresses this gap by examining consumer awareness, risk perception, and disposal behaviour, while mapping the material flow of e-waste and characterising the informal recycling sector within the city's unique socio-economic context.

## 2. Study Area: Chhatrapati Sambhajnagar (Aurangabad)

### 2.1 City Profile and Context

Chhatrapati Sambhajnagar (19.8762° N, 75.3433° E), formerly known as Aurangabad, is located in the Marathwada sub-region of Maharashtra, India. The city serves as the administrative headquarters of the Chhatrapati Sambhajnagar district and is situated approximately 335 km east of Mumbai. Key demographic and urban characteristics are summarised in Table 1.

City Parameter	Data / Description
Official Name	Chhatrapati Sambhajnagar (formerly Aurangabad)
Location	Marathwada Region, Maharashtra, India
Coordinates	19.8762° N, 75.3433° E
City Classification	Tier-III City (Urban Agglomeration)
Population (2024 est.)	~1.27 million (Municipal Corporation area)
Population Growth Rate	2.8% per annum (2011–2024)
Area (Municipal)	138.5 sq. km
Literacy Rate	87.3% (Maharashtra state average: 82.9%)
Sex Ratio	924 females per 1,000 males
Primary Industries	Automobile, Textiles, Tourism, Education, Pharma
Major Industrial Zone	MIDC Industrial Area (Chikalthana, Waluj, Shendra)
Annual E-waste Generation (est.)	~18,000 – 22,000 metric tonnes
Formal E-waste Recyclers	2 authorized facilities (MIDC area)
Informal Dismantling Units	18–22 units (unregistered, peripheral areas)
Informal Refurbishment Shops	40–50 shops (old city, scrap markets)
Nearest Metro E-waste Hub	Mumbai (335 km) / Pune (230 km)
E-waste Rules Applicability	E-Waste (Management) Rules, 2022 (GoI)
Key Heritage Zones	Bibi Ka Maqbara, Aurangabad Caves, 52 Gates

*Table 1: City Profile -Chhatrapati Sambhajnagar (Aurangabad), Maharashtra*

## 2.2 E-waste Context in Chhatrapati Sambhajnagar

The city's rapid economic development, driven by the automobile industry (companies such as Bajaj Auto, Volkswagen Group, and ancillary units in MIDC Waluj and Shendra), has resulted in rapidly increasing electronic device penetration across all socio-economic classes. The Marathwada region's administrative importance has also concentrated a large number of educational institutions, government offices, and hospitals in the city, generating significant institutional e-waste streams alongside growing household volumes. (MoEFCC, 2022; MPCB, 2023)

The city's informal e-waste economy is concentrated in two primary areas: the old city scrap market near Kaala Gate and Gulmandi, and peripheral industrial clusters near Chikalthana MIDC. These areas serve as aggregation points where scrap dealers (kabadiwala) collect discarded electronics from households before supplying them to dismantlers. A notable characteristic of Chhatrapati Sambhajnagar's e-waste landscape is its position as a regional

aggregation hub, with e-waste flowing in from smaller towns in the Marathwada region (Jalna, Parbhani, Latur) before being transported onwards to Mumbai and Delhi processing hubs. (Sengupta et al., 2022; Chel et al., 2025)



Fig.1. (A) Map of India Highlighting Maharashtra.

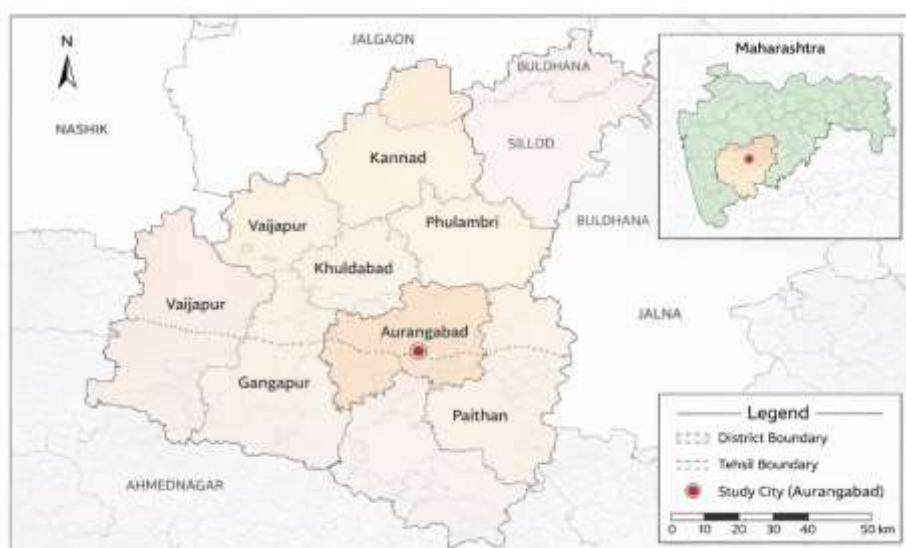


Fig. 1(B) Study area map - Chhatrapati Sambhajinagar (Aurangabad), Maharashtra, India.

### 3. Research Methodology

#### 3.1 Research Design and Questionnaire Development

This study adopted a cross-sectional survey design. The questionnaire was developed through a systematic multi-stage process. In Stage 1, a comprehensive review of validated instruments from prior e-waste behaviour studies (Borthakur & Govind, 2018; Trad & Harb, 2024; Bhat & Patil, 2014) was conducted to identify established item pools covering awareness, risk perception, and disposal behaviour. In Stage 2, an expert panel comprising three environmental engineers, two public health specialists, and one social scientist reviewed the initial item pool for content validity. Items were retained, modified, or discarded based on consensus, yielding a draft instrument of 42 items across five thematic domains: (i) socio-demographic profile, (ii) e-waste awareness and knowledge, (iii) risk perception, (iv) disposal behaviour, and (v) barriers to formal disposal. In Stage 3, the instrument was refined to 36 items following expert review, and face validity was confirmed through structured interviews with ten members of the target population representing diverse educational and occupational backgrounds.

#### 3.2 Pilot Testing and Instrument Reliability

Prior to full-scale data collection, a pilot test was conducted with 45 respondents (not included in the final sample) drawn from the four survey zones in proportions mirroring the main sampling frame. The pilot assessed item clarity, response time (target: 12–15 minutes), and completion rates. Based on pilot feedback, three items were reworded to improve comprehension, and one item assessing informal recycler contact was removed due to social desirability concerns. Internal consistency reliability was assessed using Cronbach's alpha ( $\alpha$ ) for each thematic scale. Acceptable reliability was defined as  $\alpha \geq 0.70$ , consistent with established benchmarks for social science research (Nunnally, 1978). As reported in Table 2, all five subscales demonstrated acceptable to good internal consistency, with the overall instrument yielding  $\alpha = 0.81$ .

**Table 2: Instrument Reliability Statistics (Cronbach's Alpha) by Subscale (Pilot, n = 45)**

Subscale	No. of Items	Cronbach's $\alpha$	Interpretation
E-waste Awareness & Knowledge	8	0.79	Acceptable
Risk Perception	6	0.74	Acceptable
Disposal Behaviour	7	0.76	Acceptable
Barriers to Formal Disposal	8	0.82	Good
Socio-demographic Profile	7	N/A (factual)	—
<b>Overall Instrument</b>	<b>36</b>	<b>0.81</b>	<b>Good</b>

#### 3.3 Sampling Strategy and Data Collection

A stratified random sampling design was adopted. The city was divided into four survey zones based on land-use classification: (i) Residential (old city), (ii) Commercial (Gulmandi, Kaala Gate markets), (iii) Institutional/Campus (university districts, government offices), and (iv) Peripheral industrial (MIDC Chikalthana). Sample size was determined using the Cochran (1977) formula for proportions ( $p = 0.5$ , margin of error = 4%, 95% confidence level), yielding a minimum sample of 600. Accounting for an anticipated 5% non-

response rate, a target of 650 questionnaires was distributed; 620 were returned fully completed, yielding a response rate of 95.4%. Within each stratum, respondents were selected through systematic random sampling from available household and establishment lists. Data collection was conducted over eight weeks (March–May 2024) through face-to-face administration by trained field investigators, ensuring comprehension support for respondents with lower literacy. All respondents provided informed consent, and the study protocol was reviewed and approved by the Institutional Ethics Review Committee of MGM University, Chh. Sambhajinagar.

### **3.4 Awareness Score Construction**

A composite E-waste Awareness Score (EAS) was constructed from eight binary indicator items (correct response = 1, incorrect or “do not know” = 0), yielding a score range of 0–8. Items covered: (1) familiarity with the term “e-waste”; (2) identification of environmental hazards; (3) knowledge of health risks from informal recycling; (4) recognition of valuable materials in e-waste; (5) knowledge of formal collection systems; (6) understanding of Extended Producer Responsibility (EPR); (7) awareness of E-waste (Management) Rules, 2022; and (8) knowledge of the nearest authorised collection point. Raw scores were standardised to a 0–100 scale for comparative analysis. Respondents scoring 0–24 were classified as “Low Awareness,” 25–49 as “Moderate,” 50–74 as “High,” and 75–100 as “Very High.” The mean EAS in the sample was 38.4 (SD = 14.7), placing the population on average in the Moderate awareness category. Analysis by education level and survey zone is presented in Section 4.2.

### **3.5 Statistical Analysis**

Descriptive statistics (frequencies, percentages, means, standard deviations) were computed for all variables. Chi-square ( $\chi^2$ ) tests of independence examined associations between categorical variables (e.g., education level vs. e-waste awareness category; survey zone vs. disposal method). Pearson product-moment correlation ( $r$ ) assessed linear associations between continuous awareness and behaviour scores. Binary logistic regression was employed to identify predictors of formal e-waste disposal behaviour (dependent variable: formal disposal = 1, informal/mixed = 0), with awareness score, education level, income bracket, zone, and access to collection point as independent variables. All analyses were conducted using IBM SPSS Statistics Version 26. Statistical significance was set at  $p < 0.05$  (two-tailed) for all tests. Effect sizes are reported (Cramér’s  $V$  for chi-square; odds ratios with 95% CIs for logistic regression) to contextualise practical significance alongside statistical significance.

## **4. Results**

### **4.1 Socio-demographic Profile of Respondents**

The final sample comprised 620 respondents distributed across four survey zones: Residential ( $n = 248$ , 40%), Commercial ( $n = 124$ , 20%), Institutional/Campus ( $n = 155$ , 25%), and Peripheral/MIDC ( $n = 93$ , 15%). Gender representation was 54% male and 46% female. The sample was predominantly between 25 and 44 years of age (61%), with 24% below 25 years and 15% aged 45 and above. Educational attainment was distributed as follows: secondary level (28%), undergraduate (34%), postgraduate (27%), and no formal qualification (11%). Monthly household income was categorised as below ₹25,000 (36%), ₹25,000–50,000 (41%), and above ₹50,000 (23%), broadly reflecting the city’s predominantly middle-income socio-economic profile. Institutional respondents

(students, faculty, government employees) constituted 42% of the sample, while the remaining 58% were engaged in trade, manufacturing, or household activities.

#### 4.2 E-waste Awareness by Education Level and Survey Zone

Table 2a presents mean E-waste Awareness Scores (EAS) stratified by education level and survey zone, providing a multivariate overview of awareness distribution across the sample. Postgraduate respondents recorded the highest mean EAS (54.2, SD = 12.1), followed by undergraduates (42.6, SD = 13.4), secondary-level respondents (28.3, SD = 11.8), and those with no formal qualification (18.7, SD = 9.6). One-way ANOVA confirmed statistically significant between-group differences ( $F(3,616) = 47.3, p < 0.001, \eta^2 = 0.19$ , large effect). Post-hoc Tukey tests revealed significant pairwise differences between all education groups (all  $p < 0.01$ ) except between secondary and no-qualification groups ( $p = 0.09$ ). By survey zone, Institutional/Campus respondents recorded the highest mean EAS (52.8, SD = 11.7), significantly exceeding Residential old-city respondents (mean EAS = 31.4, SD = 12.9; difference = 21.4 points,  $p < 0.001$ ). Commercial and Peripheral zone respondents showed intermediate scores (39.6 and 34.1, respectively). These zone-level differences confirm that geographic proximity to educational and institutional infrastructure is a significant correlate of e-waste awareness, independent of individual educational attainment.

Table 2a: Mean E-waste Awareness Scores (EAS, 0–100) by Education Level and Survey Zone ( $n = 620$ )

Group	n	Mean EAS	SD	Awareness Category
<b>BY EDUCATION LEVEL</b>				
No formal qualification	68	18.7	9.6	Low
Secondary education	174	28.3	11.8	Moderate
Undergraduate	211	42.6	13.4	Moderate
Postgraduate	167	54.2	12.1	High
<b>BY SURVEY ZONE</b>				
Residential (old city)	248	31.4	12.9	Moderate
Commercial	124	39.6	11.2	Moderate
Institutional/Campus	155	52.8	11.7	High
Peripheral / MIDC	93	34.1	13.4	Moderate

Note: ANOVA  $F(3,616) = 47.3, p < 0.001$  (by education);  $F(3,616) = 39.8, p < 0.001$  (by zone). EAS = E-waste Awareness Score (0–100).

### 4.3 Consumer Awareness of E-waste Hazards and Regulations

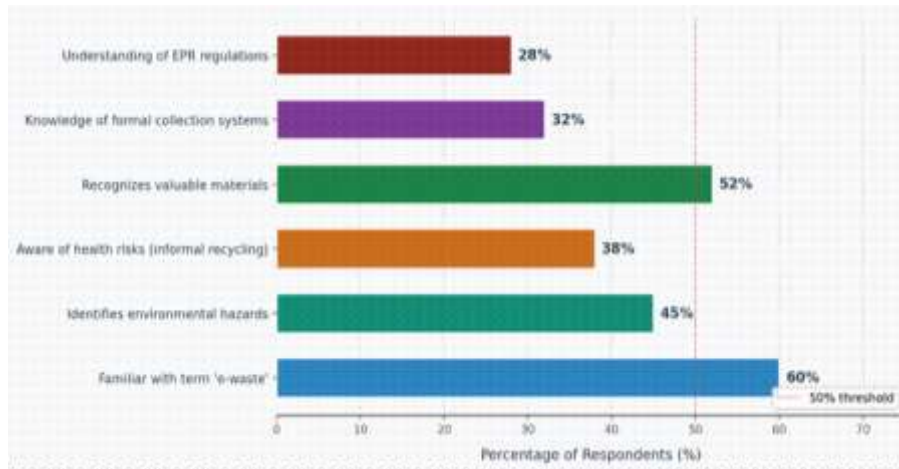


Figure 2: Consumer Awareness Indicators for E-waste - Chhatrapati Sambhajnagar (Aurangabad), Maharashtra (n = 620)

Awareness Indicator	Respondents (n)	Percentage (%)
Familiar with the term 'e-waste'	372	60%
Can identify environmental hazards of e-waste	279	45%
Aware of health risks from informal recycling	236	38%
Recognises valuable materials in e-waste (gold, copper)	322	52%
Knowledge of formal collection systems in the city	198	32%
Understanding of Extended Producer Responsibility (EPR)	174	28%
Aware of E-waste (Management) Rules, 2022	137	22%
Know the nearest authorised e-waste collection point	99	16%

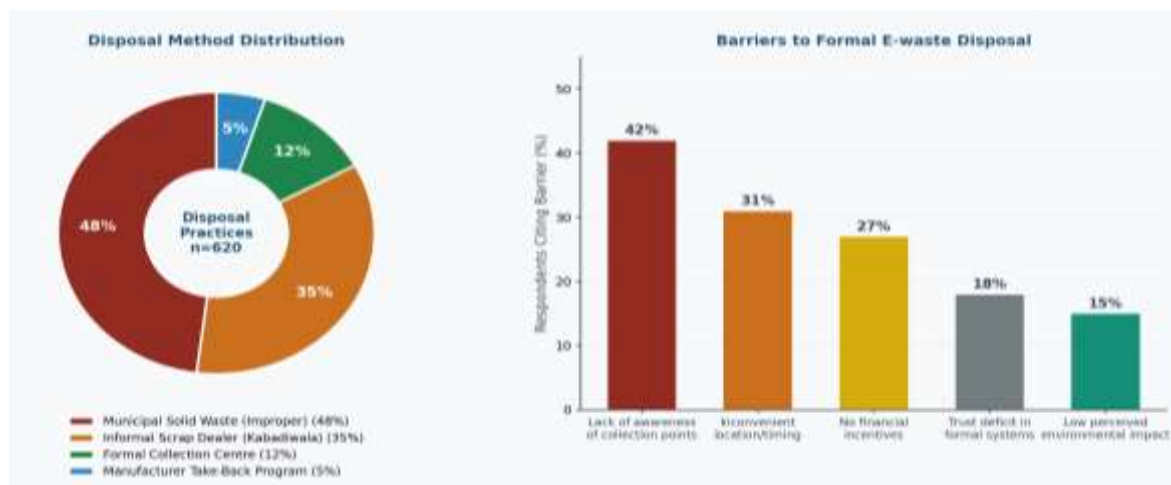
Table 3: Consumer Awareness Indicators for E-waste Management (n = 620)

Chi-square analysis revealed a significant association between educational level and awareness of e-waste hazards ( $\chi^2 = 18.42$ ,  $df = 3$ ,  $p < 0.01$ ), with postgraduate respondents demonstrating significantly higher awareness compared to those with secondary education. Additionally, respondents residing in institutional/campus areas (near universities) showed 28% higher awareness scores compared to old-city residential respondents ( $\chi^2 = 12.74$ ,  $p < 0.05$ ).

### 4.4 E-waste Disposal Practices and Barriers

Analysis of disposal behaviour revealed concerning patterns. Approximately 48% of respondents (n=298) disposed of e-waste along with regular municipal solid waste. Approximately 35% (n=217) sold old electronics to informal scrap dealers (kabadiwala). Only 12% (n=74) utilised formal collection centres, while 5% (n=31)

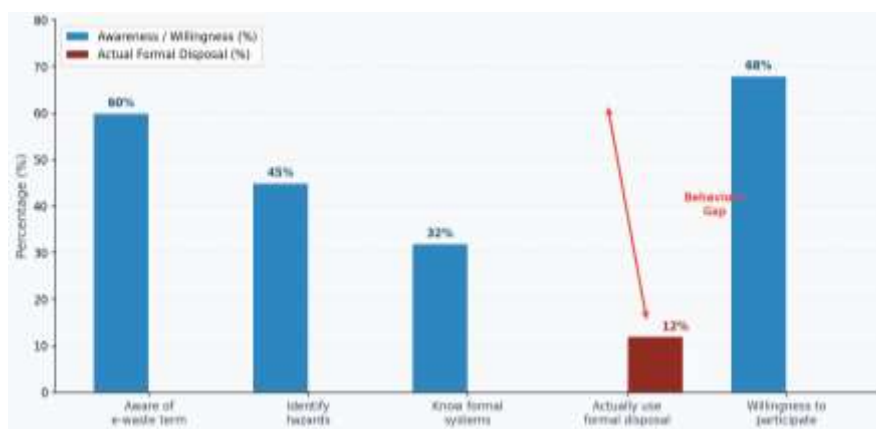
participated in manufacturer take-back programs. Figure 2 presents the disposal method distribution and primary barriers to formal e-waste disposal.



**Figure 3: E-waste Disposal Practices and Barriers - Chhatrapati Sambhajinagar (Aurangabad) (n = 620)**

#### 4.5 Awareness–Behaviour Gap and Logistic Regression Analysis

A critical finding of the study is the pronounced gap between consumer awareness and actual disposal behaviour. While 60% of respondents demonstrated basic awareness of e-waste hazards, only 12% utilized formal collection systems. Pearson correlation analysis demonstrated a moderate positive relationship between awareness of environmental risks and willingness to participate in formal e-waste management ( $r = 0.42, p < 0.01$ ). However, the relationship between awareness and actual disposal behaviour was substantially weaker ( $r = 0.26, p < 0.05$ ). It is important to note that both correlation values represent moderate effect sizes, explaining 18% and 7% of shared variance respectively. These associations are therefore interpreted as indicative of a meaningful, though partial, relationship between awareness and behaviour; causal inference is not appropriate given the cross-sectional design. The gap confirms, consistent with prior literature, that awareness alone is insufficient to drive behavioural change without supporting infrastructure and incentive structures. Figure 3 illustrates this awareness-behaviour gap across key dimensions. (Borthakur & Govind, 2018; Deshwal, 2025)



**Figure 4: Awareness–Behaviour Gap in E-waste Management - Chhatrapati Sambhajinagar (Aurangabad), n = 620.**

To identify predictors of formal e-waste disposal behaviour, a binary logistic regression model was fitted (dependent variable: formal disposal = 1 vs. informal/mixed disposal = 0; n = 620). The model included five independent variables: E-waste Awareness Score (EAS), education level, income bracket, survey zone, and self-reported access to an e-waste collection point. The full model was statistically significant ( $\chi^2(10) = 87.4$ ,  $p < 0.001$ ; Nagelkerke  $R^2 = 0.24$ ), indicating moderate predictive capacity. Results are presented in Table 4.

Table 4: Binary Logistic Regression – Predictors of Formal E-waste Disposal Behaviour (n = 620)

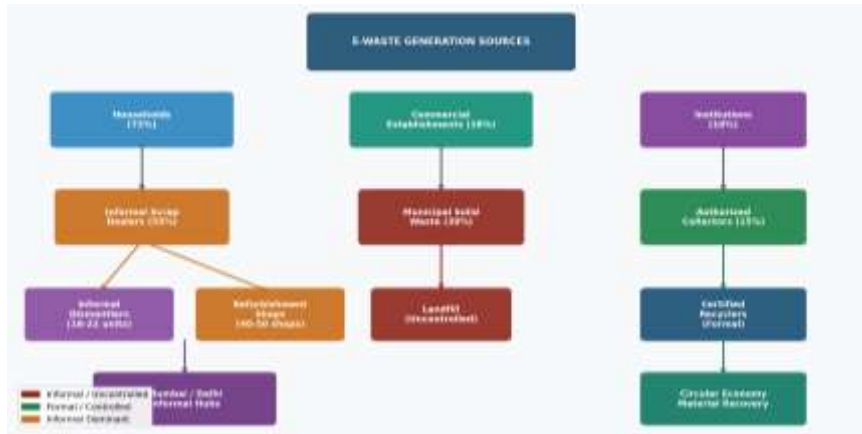
Predictor Variable	B	S.E.	OR (Exp B)	95% CI	p-value
E-waste Awareness Score (EAS)	0.032	0.009	1.033	1.015–1.051	< 0.001
Education (Postgraduate vs. Secondary)	0.81	0.26	2.25	1.34–3.77	0.002
Income (>₹50k vs. <₹25k/month)	0.49	0.22	1.63	1.05–2.52	0.028
Zone (Institutional vs. Residential)	0.74	0.25	2.10	1.28–3.43	0.004
Access to Collection Point (Yes vs. No)	1.12	0.28	3.06	1.76–5.31	< 0.001

OR = Odds Ratio; CI = Confidence Interval; Model:  $\chi^2(10) = 87.4$ ,  $p < 0.001$ ; Nagelkerke  $R^2 = 0.24$ ; Hosmer-Lemeshow  $\chi^2(8) = 6.3$ ,  $p = 0.61$  (good fit).

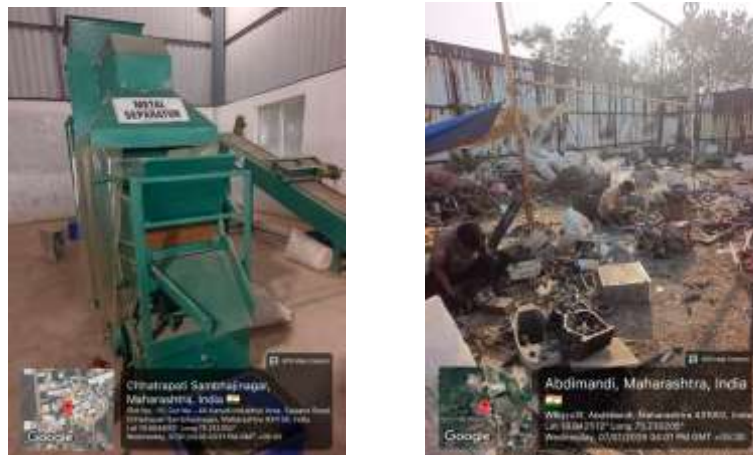
The strongest predictor of formal disposal was access to a collection point (OR = 3.06, 95% CI: 1.76–5.31,  $p < 0.001$ ), indicating that respondents who reported knowing the location of a nearby authorised collection point were approximately three times more likely to use formal channels. E-waste Awareness Score was also a significant predictor (OR = 1.033 per unit increase;  $p < 0.001$ ), as were postgraduate education (OR = 2.25,  $p = 0.002$ ) and institutional zone residence (OR = 2.10,  $p = 0.004$ ). Higher income bracket was a significant but weaker predictor (OR = 1.63,  $p = 0.028$ ). These findings corroborate the Pearson correlation results and underscore that while awareness is a statistically significant associate of formal disposal behaviour, infrastructure access is the dominant practical determinant in this context.

#### 4.6 E-waste Material Flow Analysis

Material flow analysis combined three convergent data sources to estimate pathway proportions: (i) survey-reported disposal routes from 620 respondents; (ii) structured interviews with key stakeholders including operators of the 18–22 informal dismantling units, 40–50 refurbishment shops, and 2 authorised recyclers; and (iii) annual tonnage estimates from MPCB (2023) and the published material flow analysis for this city reported in Chel et al. (2025). Cross-triangulation of these sources yielded the following estimated pathway distribution for the city’s annual e-waste generation of approximately 18,000–22,000 metric tonnes: (i) household to scrap dealer (kabadiwala) to informal dismantler, approximately 55% ( $\approx 9,900$ – $12,100$  MT); (ii) direct disposal with municipal solid waste, approximately 30% ( $\approx 5,400$ – $6,600$  MT); and (iii) institutional collection through authorised channels, approximately 15% ( $\approx 2,700$ – $3,300$  MT). The 55% informal network figure is consistent with the survey finding that 35% of respondents sold to kabadiwala and a further proportion reported mixed informal routes, together with stakeholder interview estimates of informal unit throughput. These proportions represent indicative estimates derived from triangulated evidence rather than directly metered waste audits, and carry uncertainty ranges reflecting the informal sector’s heterogeneity. Figure 5 presents the complete material flow diagram. (Chel et al., 2025; Sengupta et al., 2022; MPCB, 2023)



**Figure 5: E-waste Material Flow - Chhatrapati Sambhajnagar (Aurangabad): Informal vs. Formal Pathways**



**Figure 6: Formal and Informal e-waste practices**

## 5. Discussion

### 5.1 Awareness–Behaviour Gap in Tier-III Cities

The findings reveal a substantial awareness-behaviour gap in e-waste management practices among consumers in Chhatrapati Sambhajnagar. This disconnect between knowledge and action reflects broader challenges in translating environmental awareness into sustainable behaviour, and has been documented across similar Tier-III urban contexts in India. The city's socio-economic profile - characterised by a predominantly middle-income population (52%), high literacy rates (87.3%), and a large student population - suggests that awareness deficits are not the primary constraint. Rather, the absence of accessible formal collection infrastructure and the lack of financial incentives constitute the dominant barriers. (Bhat & Patil, 2014; Singh et al., 2023; Trad & Harb, 2024)

### 5.2 Global Comparative Perspective

The following sub-sections contextualise the Chhatrapati Sambhajnagar findings within global e-waste governance frameworks. In each case, specific features of international experience are explicitly linked to patterns observed in this study, namely: the awareness–behaviour gap, the dominance of informal networks, and the

relative effectiveness of infrastructure-based versus awareness-based interventions. The comparison is structured to identify transferable lessons rather than to assert equivalence between heterogeneous contexts.

### **5.2.1 United States**

In the United States, consumer awareness of e-waste is generally higher (75-82%), with participation rates ranging from 15% in states without mandatory legislation to over 50% in states with comprehensive EPR laws (California, Washington). Unlike Chhatrapati Sambhajnagar's informal-sector-dominated system, the U.S. e-waste recycling industry is predominantly formal, with certified recyclers handling approximately 70% of collected e-waste. The key differentiator is state-level regulatory enforcement and retail take-back mandates that create accessible collection touchpoints. (Parajuly et al., 2020)

### **5.2.2 Europe**

European countries demonstrate the highest formal collection rates globally (40-65%) driven by the WEEE Directive. Studies from Germany, Switzerland, and the Netherlands report awareness levels exceeding 85%. However, even in Europe, approximately 35% of e-waste still enters informal channels, highlighting that complete formalisation remains challenging even in highly regulated environments. The European experience demonstrates that deposit-refund schemes and incentive-based programs significantly outperform awareness campaigns alone. (Li & Sun, 2023)

### **5.2.3 China**

China, the world's largest e-waste generator, presents instructive parallels. Urban consumer awareness has increased to 65-70% following government campaigns, yet informal processing persists in regions like Guiyu despite regulatory crackdowns. China's partial success in formalising higher-value waste streams through parallel formal and informal sector regulation offers a policy model relevant to Chhatrapati Sambhajnagar's context.

### **5.2.4 South-East Asia**

Countries like Singapore (formal collection: 35-45%) and Malaysia have achieved higher formal participation through strong EPR legislation. Vietnam and Thailand - with awareness levels of 45-55% face challenges strikingly similar to Chhatrapati Sambhajnagar: strong informal sector networks, transboundary e-waste flows, and limited formal infrastructure. (Parajuly et al., 2019; Mohammed & Kaida, 2024)

### **5.2.5 Africa**

African nations face the most acute e-waste challenges, with awareness typically at 25-40% and over 80% of e-waste handled informally. Communities in Agbogbloshie (Ghana) and Dandora (Kenya) suffer severe health impacts. Unlike India, which has domestic EPR legislation and established informal recycling networks, African countries face the dual challenge of managing both domestically generated and imported e-waste with extremely limited institutional capacity. (Owusu-Sekyere et al., 2022; Lepawsky, 2022)

## **5.3 Integration of Informal Sector- A Chhatrapati Sambhajnagar Model**

Taken together, the global evidence reviewed in Sections 5.2.1–5.2.5 yields three conclusions directly relevant to interpreting the Chhatrapati Sambhajnagar dataset. First, the awareness–behaviour gap documented in this study

(60% awareness vs. 12% formal disposal) is not unique to India but reflects a pattern observed across rapidly urbanising middle-income settings, including Vietnam, Thailand, and urban China, where awareness campaigns have outpaced infrastructure development. Second, the dominance of informal networks (estimated at ~55% of e-waste flows) mirrors the situation in West African cities and transitional Chinese contexts, and international evidence consistently shows that regulatory crackdowns without parallel infrastructure investment fail to reduce informal sector share. Third, and most relevant to policy design, the logistic regression finding that infrastructure access (OR = 3.06) is the strongest individual predictor of formal disposal aligns with the European and Californian experience that accessible take-back infrastructure — rather than awareness alone — drives behavioural change. These analytical parallels strengthen the empirical case for the infrastructure-first policy priorities recommended in Section 5.4.

The 18-22 informal dismantling units and 40-50 refurbishment shops operating in Chhatrapati Sambhajnagar constitute a significant de facto e-waste management system. Rather than attempting elimination, policy should prioritise integration: providing training, PPE, and linkages to formal recyclers can improve both environmental outcomes and worker welfare while maintaining economic viability. The city's MIDC industrial area, which already hosts two authorised recyclers, offers an anchor infrastructure around which a formalised hybrid model could be developed.

#### **5.4 Policy Implications for Tier-III Cities**

The study identifies four priority interventions for Chhatrapati Sambhajnagar and comparable Tier-III cities: (1) Establish decentralized e-waste collection points at electronics retail stores, municipal offices, and residential complexes across all four survey zones; (2) Strengthen EPR implementation by enforcing producer collection targets specifically for Tier-III cities; (3) Introduce financial incentives such as buyback schemes or municipal tax credits for formal e-waste submission; and (4) Develop a Marathwada-level regional e-waste management framework that recognizes the city's role as an aggregation hub for surrounding smaller towns.

#### **6. Conclusion**

Electronic waste management in Chhatrapati Sambhajnagar (Aurangabad) and Indian Tier-III cities more broadly is constrained not by awareness alone but by inadequate formal collection infrastructure, weak EPR enforcement, and strong dependence on informal recycling networks. The present study demonstrated that although 60% of respondents possessed basic awareness of e-waste hazards, nearly half (48%) continued to dispose of electronic waste with municipal refuse, indicating a persistent awareness-behaviour gap ( $r = 0.26$  between awareness and actual behaviour vs.  $r = 0.42$  for willingness). Material flow analysis revealed that informal networks comprising 18-22 dismantling units and 40-50 refurbishment shops handle approximately 55% of the city's estimated 18,000-22,000 metric tonnes of annual e-waste generation.

Comparative global evidence further supports that infrastructure availability and incentive-driven governance are more effective than awareness campaigns alone in achieving sustainable disposal behaviour, a pattern observed across diverse regulatory contexts from California to the European Union to urban China. The policy recommendations arising from this study are grounded directly in the survey evidence: the logistic regression finding that infrastructure access is the strongest individual predictor of formal disposal (OR = 3.06) provides the empirical basis for prioritising decentralised collection point expansion; the formal sector's current 15% share of

estimated e-waste flows supports the case for strengthened EPR enforcement targeting Tier-III cities specifically; and the documented role of the 18–22 informal dismantling units in handling the majority of the city’s e-waste underscores the practical necessity of integration rather than elimination strategies. These evidence-based priorities are consistent with, though not derived from, broader circular economy discourse. Future research should prioritise longitudinal behavioural assessment to determine whether awareness–behaviour gaps narrow with improved infrastructure access, as well as metered material-flow quantification and cost-benefit analyses of incentive mechanisms across Tier-III urban systems to support evidence-based policy refinement in India’s Marathwada and comparable regions.

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